RSRM

TWR-75589
ECS SS10962

SPACE SHUTTLE

Reusable Solid Rocket Motor

STS-103 Flight Readiness Review/CoFR

Motor Set RSRM-73

19 November 1999

Presented by John W. Edwards

Thiokol Propulsion™

From Cordant Technologies

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Agenda

Flight Readiness Review/CoFR

1.0 Previous Flight Assessment—STS-93

2.0 Certification Status—**No Constraints**

3.0 Changes Since Previous Flight

4.0 Configuration Inspection

- 4.1 As-Built Versus As-Designed and Hardware Status—**No Issues**
- 4.2 Hardware Changeouts Since ET/SRB Mate Review—**None**

5.0 SMRB Nonconformances

6.0 Technical Issues/Special Topics

7.0 Readiness Assessment

Backup LCC and Contingency Temperatures for STS-103

Previous Flight Assessment—STS-93

Disassembly Evaluation Summary—Status of Disassembly Activity

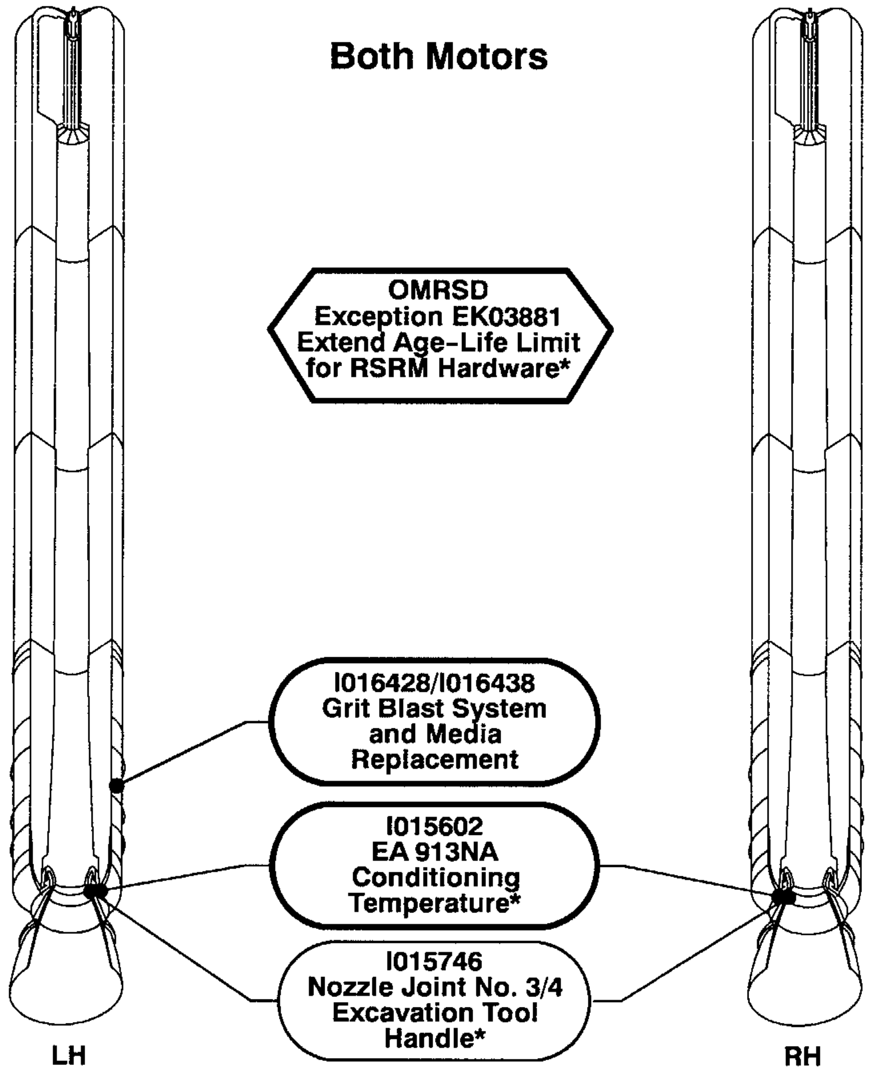
KSC Operations	LH RSRM	RH RSRM	Remarks
Initial LH/RH SRB viewing	Complete	Complete	
SRB/SRM walkaround assessment	Complete	Complete	
Demate/evaluate aft exit cone (AEC)	Complete	Complete	
Remove/evaluate safe and arm (S&A) and operational pressure transducers (OPTs)	Complete	Complete	
Remove/evaluate nozzle	Complete	Complete	No pocketing erosion
Ship nozzles by truck	Complete		
Ship S&As	Complete		
Ship AECs by truck	Complete		
Remove/evaluate stiffener rings/stubs	Complete	Complete	
Remove/evaluate igniter	Complete	Complete	
Demate/evaluate field joints/evaluate insulation	Complete	Complete	
Install handling rings	Complete	Complete	
Ship igniters and stiffener rings by truck	Complete		
Ship segments by rail	Complete	Complete	
Utah Operations			
Receive nozzles	Complete		
Receive S&As	Complete		
Disassemble/evaluate nozzle (joint No. 4 and 5)	Complete	Complete	
Disassemble/evaluate nozzle (joint No. 2 and 3)	Complete	Complete	
Receive AECs	Complete		
Disassemble/evaluate S&A	Complete	Complete	No cause confirmed for slow S&A rotation - Minor pinching of S&A power return wire insulation not a factor
Washout nozzle phenolics	Complete	Complete	
Washout nozzle AEC phenolics	Complete	Complete	
Receive igniters and stiffener rings	Complete		
Receive segments	Complete	Complete	
Measure and evaluate aft dome and LH segment insulation	Dec 1999	Complete	
Measure and evaluate igniter insulation	Dec 1999	Complete	

Changes Since Previous Flight

Summary

Number of Changes Since STS-96

Class I Hardware	0
Class I Engineering	2
Class II Hardware	0
Critical Process	3
Noncritical Process	3
Supplier Process	0
LCC	0
OMRSD	4



Both Motors

- I015682/I015911 Spray-In-Air and KOH Addback*
- C015192 Hydrotest Tooling Spools
- Q015169 Microtrac for Aluminum Acceptance
- RSRM Block Model Update
- Propellant Burn Rate Scale Factor Update

* See summary table for changes previously presented, incrementally implemented, or not affecting form, fit or function

Changes Since Previous Flight

Summary (Concluded)

Title	Type	PRCB Control No.	Reason	Justification
Spray-in-air Cleaning of Flight Hardware*	Critical Process	S074898	Environmental regulations, Maintain stable bath conditions	Test Demonstration Inspection
EA913NA Adhesive Premixing Conditioning Time**	Critical Process	S071503	Storage temperature lowered (40° to 15°F) requiring longer conditioning time prior to mixing	Similarity Demonstration Inspection
New Excavation Tool Handle for Use on RSRM-Nozzle Joint No. 3 and 4 Backfill Operations**	Noncritical Process	SR0858	Ergonomics and safety, Reduce variation in excavation process, Improve depth-of-cut control	Similarity Test Demonstration Inspection
Extend Grease Age-Life Limit for RSRM Hardware*	OMRSD	S053293NU	One-year age-life requirement has been exceeded	Test Demonstration

* Incrementally incorporated change previously presented
** Change not affecting form, fit, or function of hardware

Changes Since Previous Flight—Approved

Class I Engineering

Propellant Burn Rate Scale Factor Update
Criticality: 2H
Status: SR1094 statused at PRCB on 5 Aug 1999

Change Description

Update the scale factor used to determine the full-scale burn rate from the 5-in. CP burn rates from 1.0173 to 1.0194

Reset the 5-in. CP target burn rate from 0.362 to 0.361 in./sec to maintain a full-scale target of 0.368 in./sec (effective STS-110)

Reason for Change

The average reconstructed subscale to full-scale burn rate has been above the expected 1.0173 since approximately STS-69 and affects the motor target burn rate and performance predictions

Basis for Certification

Analysis and Demonstration: Analysis of the demonstrated performance since the last significant process change has shown the scale factor change to be statistically significant and repeatable

Changes Since Previous Flight—Approved

Class I Engineering

ECP SRM-3454, RSRM Block Model Update
Criticality: 1
Status: CR S052189CT approved at PRCB on 5 Aug 1999

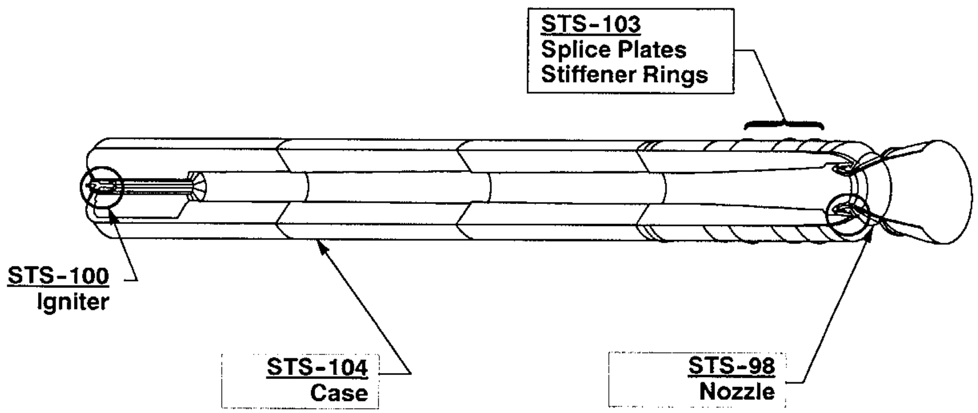
Change Description	Reason for Change	Basis for Certification
The RSRM "block model" math model used for predicting RSRM thrust-time trace has been revised to reflect the expected flight and static test performance of current materials and processes used in propellant production	Provide the Space Shuttle program with the most accurate performance predictions possible	Analysis and Demonstration: The new "block model" is based on analysis of the demonstrated flight and static test performance of motors since the last significant process change

Changes Since Previous Flight—Approved

Critical Process

OCRs I016428/I016438, Grit Blast System and Media Replacement in the Insulation and Component Work Center
Status: Approved at PRCB on 23 Sep 1998

Change Description	Reason for Change	Basis for Certification
Replace the Pangborn grit blast system with the Clemco grit blast system for automated grit blast operations and establish the Clemco as an alternate to the Pangborn for manual grit blast operations	Facility upgrade	Test: Bond testing of metal and phenolic components (vulcanized, adhesive, and paint bonds) verified equivalent bond strengths Material removal rate testing verified equivalent removal rates and Conscan values Demonstration: FSM-7 Inspection: All acceptance criteria (blacklight, visual, Conscan, witness panel) are unchanged
Replace Zirclean grit blast media with Biasill XL™	Zirclean media no longer available	



New Grit Blast System Implementation

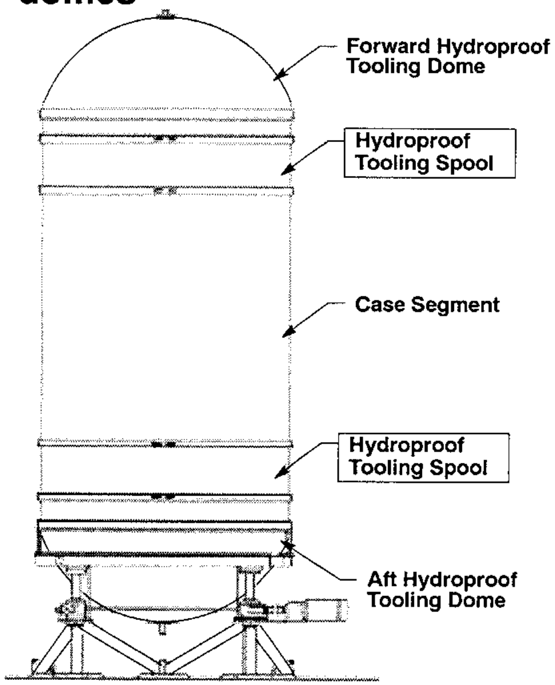
Changes Since Previous Flight—Approved

Noncritical Process

OCR C015192, Hydrotest Tooling Spools
Status: Approved

Change Description

Add two 38-in.-long D6AC steel tooling spools to case hydrotest configuration between cylinder and tooling domes



Reason for Change

More realistic proof test of joint region. Spools isolate cylinder joints from dome restraint. Reduces reliance on NDT

Basis for Certification

Analysis: Analysis showed enhanced proof test in the joint region

Test: Full-scale testing showed excellent correlation between strain gage data and predicted values

Demonstration: FSM-7

Changes Since Previous Flight—Approved

Noncritical Process

OCR Q015169, Implement Microtrac for Acceptance Testing of Aluminum Powder
Status: CR S071508 approved at PRCB on 23 Oct 1997

Change Description	Reason for Change	Basis for Certification
Replace Coulter Counter with Microtrac for particle size distribution acceptance testing of aluminum powder	Coulter Counter obsolete and inoperable	Testing: Side-by-side testing on 36 lots of aluminum showed equivalent results. Also showed that Microtrac is more discriminating Demonstration: FSM-7

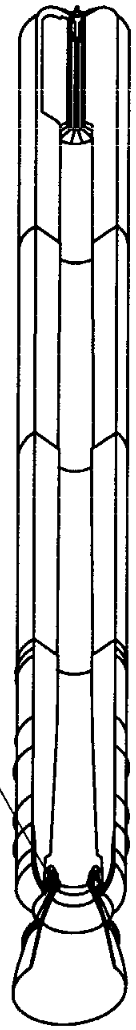
SMRB Nonconformances

Summary

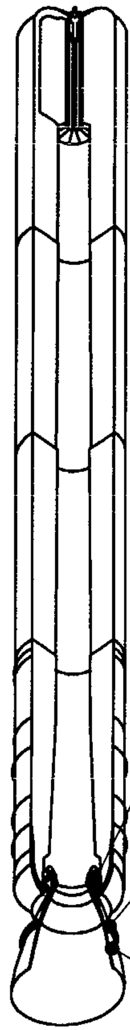
All Segments

DR 429047-01
Contaminated HB Polymer
Suspect Condition
Use As Is

PD 429707-01*
Cowl Vacuum Loss During Cure
Use As Is



LH



RH

DR 424500-03
Forward End Ring Flange-to-Flange Height
Limited Use

DR 430491-01*
Blended Defects in Aft Dome Sealing Surface
Repair/Limited Use

DR 427369-01*
High-Density Indications in Aft Exit Cone Glass-Cloth Phenolic
Use As Is

Detailed nonconformance discussions included, unless resulting flight hardware is within family of previous flight experience (*) or reuse issue only (**)

SMRB Nonconformances

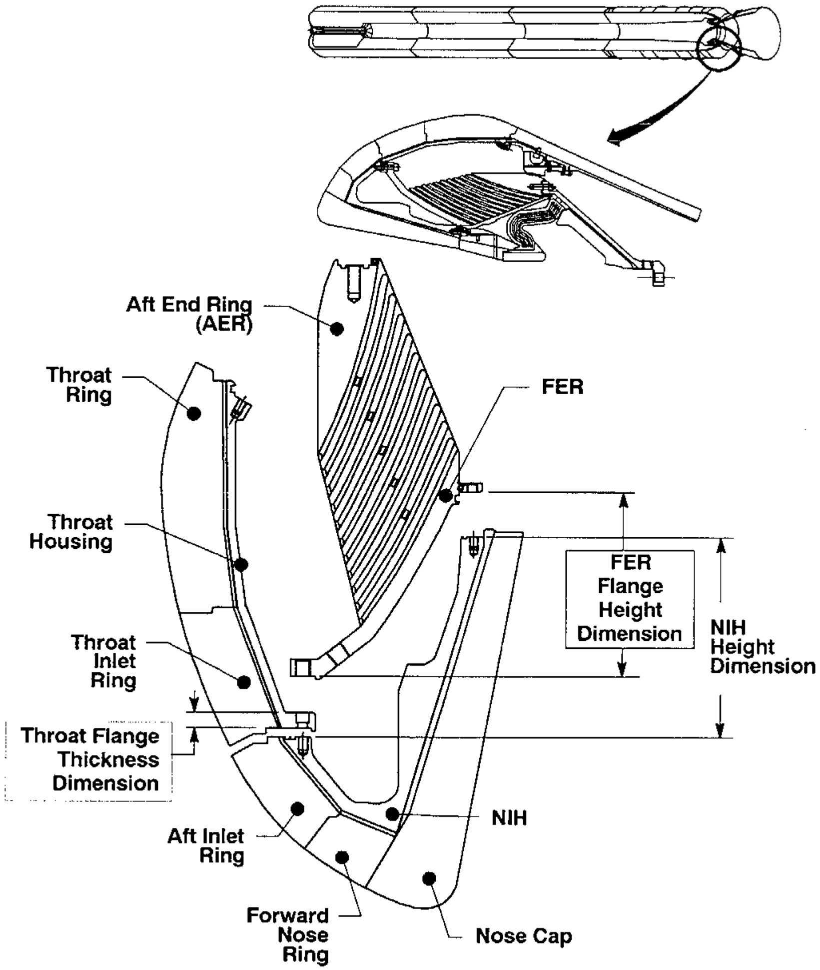
Summary

LH/RH HB Polymer—DR 429047-01

- Suspect condition—contamination in HB polymer propellant constituent
- Two small pieces of polyethylene sheet measuring 1.20-in. maximum length were found on the perforated bucket screen (0.125 in. opening) after HB polymer off-load (first of four screening processes)
    - Circulation through 20-mesh screen detected only minor additional contamination (second of four screening processes)
- Pre-mix screening detected no additional contamination (third and fourth of four screening processes)
- Testing demonstrated ability of 20-mesh screen to retain contaminants greater than 0.25 in. in length
- Engineering analysis of contaminants up to 0.40 in. in length shows either no effect or positive margins for propellant structural properties, ballistics, thermal protection, and nozzle impact
- Laboratory test results confirm that additional screening through the 20-mesh screen did not alter the physical or chemical properties of the polymer

SMRB Nonconformances

Summary



Flange Height Mismatch Worst-Case Tolerance Stackup

-0.025 in. $\leq$ FER flange height + throat flange thickness - NIH height $\leq$ 0.025 in.

RH Forward End Ring (FER)—DR 424500-03

- FER flange-to-flange height of 11.160 in. location violates the criterion of 11.155 in. maximum
- FER flange-to-flange height flag criterion established to control residual stress in phenolic bondlines due to housing flexure
- Detailed assessment of actual FER-to-nose inlet housing (NIH) shows maximum mismatch for this assembly is 0.013 in.
  - Well within allowable $\pm$0.025-in. mismatch
- Silane primer used on this nose inlet assembly (NIA) bondline results in increased adhesive capability compared to pre-STS-76 NIA bondlines
- Metal/phenolic bonding loads, other bonding parameters, and temperature exposure (storage and transportation) well within family

Technical Issues/Special Topics

Misidentified Failure Mode Nozzle Joint No. 2

Observation

- Review of the FMEA/CIL document determined that one leak path through RSRM nozzle joint No. 2 had not been properly identified

Concern

- Does identified failure mode change the retention rationale for nozzle joint No. 2

Discussion

- The identified joint No. 2 failure mode is not a hardware issue; hardware and processing of joint No. 2 have not changed
- Joint No. 2 design is robust
    - Joint No. 2 has never experienced primary O-ring damage or gas leakage past the primary O-ring or leak check port plug (155 flight and static test motors)
        - Postflight evaluations typically show gas paths in the RTV
    - Postflight inspections verify no heat-affected paint in the forward end ring-to-cowl gap (thus validating analysis that gap region is thermally benign)
        - RTV gas paths and the joint configuration do not preclude pressurization of leak check plug/region

Technical Issues/Special Topics

Misidentified Failure Mode Nozzle Joint No. 2 (Cont)

Discussion (Cont)

- Leak check port plug uses highly reliable shoulder packing seal under high compression
- Testing (both directions) confirms plug will function and O-ring will seal under extremely adverse conditions
  - Plug seals with through-cut in O-ring, groove through threads, finger-tight torque, and maximum (0.003 in) standoff
  - Plug stays seated with less than 1 in.-lb torque and NSTS 07700 vibrational loads
- Joint No. 2 inspection process ensures that the leak check port plug is properly installed, torqued, and seated
- Failure of the leak check port plug seal would not result in loss of flight or mission
  - Both the primary O-ring and leak check port plug are redundant with the secondary O-ring
  - Conservative thermal analysis indicates no challenge to secondary seal integrity due to gas leakage through plug
  - No credible scenario for joint seal failure

Technical Issues/Special Topics

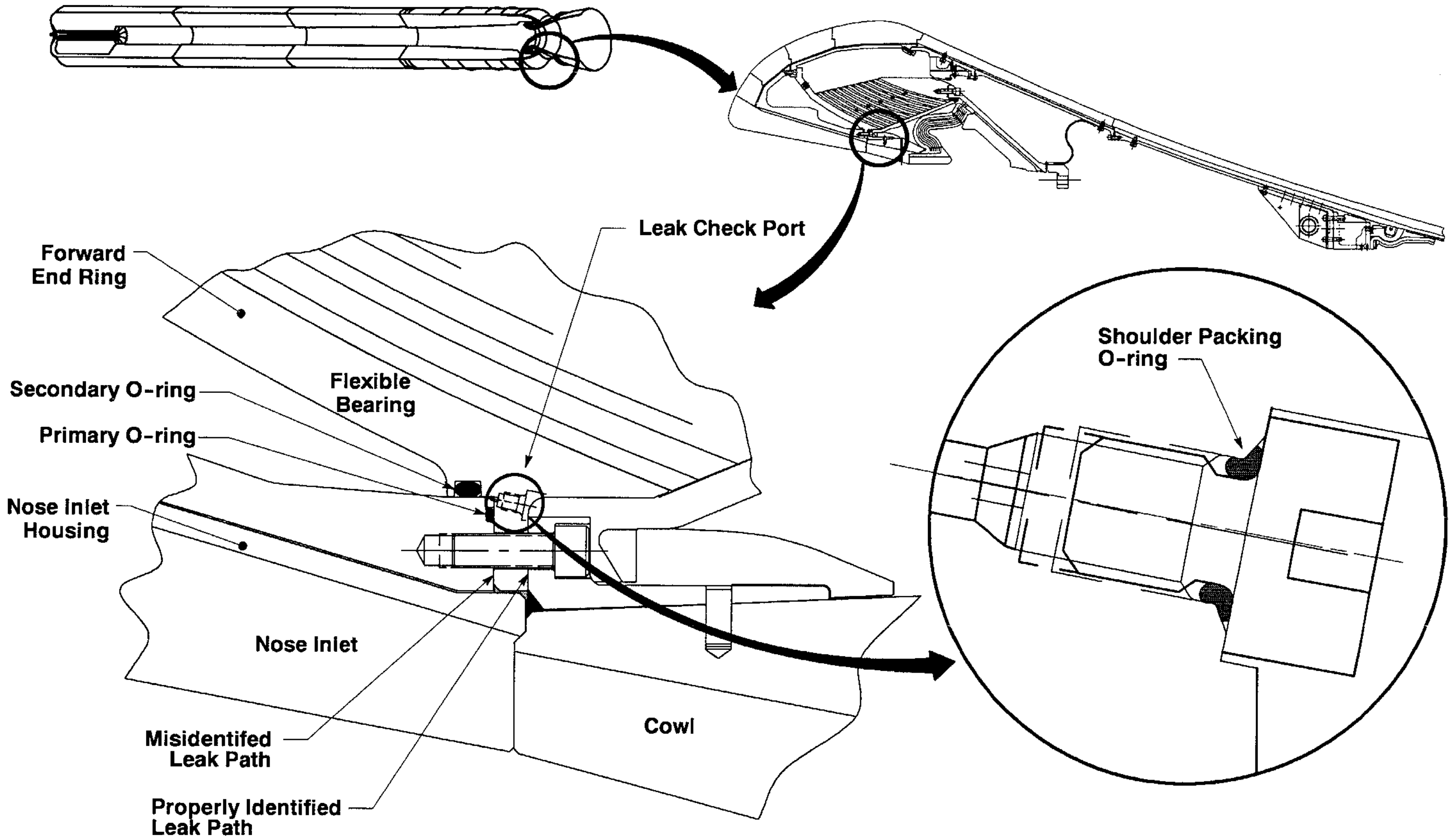
Misidentified Failure Mode Nozzle Joint No. 2 (Cont)

Flight Rationale

- Postflight inspection shows that the joint No. 2 design is robust with no leakage past the primary seals
- Joint No. 2 inspection process ensures that the leak check port plug is installed and properly seated
- Testing in both directions confirms no leakage past primary O-ring seal under extreme adverse conditions
- Analysis confirm that failure of the leak check port plug seal would not result in loss of flight or mission
- STS-103 is safe to fly

Technical Issues/Special Topics

Misidentified Failure Mode Nozzle Joint No. 2 (Cont)



Nose Inlet-to-Forward End Ring Joint Leak Check Port and Plug

Technical Issues/Special Topics

HVN RI-06-003/RI-06-004, LH/RH AEC Shipping Temperature Excursions

Observation

- Temperature data for the LH and RH AECs during transport to KSC via railcar, documents a maximum temperature inside the railcar which violates established flag criteria (HVN Limit SB: maximum of 107°F; Is: maximum of 114°F)

Disposition

- Use as is

Concern

- Exposure to high temperature can contribute to bondline residual stresses

Discussion

- STS-103 AEC "significant indicators" are equivalent to or within family of STS-89
  - Average daily temperatures above 107°F are equivalent
  - Witness panel bond strengths comparable and typical
  - STS-103 indicators of residual stress in bondline (e.g. Coe-flex measurements, seating pressure) significantly lower than STS-89
  - STS-89 AECs successfully flown with no performance issues
- STS-103 AEC "significant indicators" are within family of STS-97
  - STS-97 AECs were verified by ultrasonic inspection to have no unbonds
- Structural analysis predicts no bond failures
  - Analytical models validated by full-scale test articles and STS-97 UT inspection
- Current AEC bondlines are robust due to significant process enhancements over time

Technical Issues/Special Topics

HVN RI-06-003/RI-06-004, LH/RH AEC Shipping Temperature Excursions (Cont)

Discussion (Cont)

- Worst case assessment is local unbonding adjacent to bondline shims
- Five low-probability, independent failures required to fail nozzle: gas path in RTV backfill, gas past primary seal, gas past polysulfide, large unbond, and gas through shearpins (failure probability conservatively estimated at better than 1 in 1,000,000)

Flight Rationale

- AEC temperature exposure is in-family of STS-89 which flew with no performance issues
- AEC temperature exposure is in-family of STS-97 which was verified by UT inspection to have no unbonds
- Structural analysis predicts no bond failures
- Current AEC bondlines robust
- Very low probability of potential local unbonds caused by residual stress
- STS-103 is safe to fly

Technical Issues/Special Topics

STS-103 Field Joint Heater Performance Concern

Observation

- During field joint heater checkout in the VAB, the temperature delta between sensors exceeded the OMRSD maximum of 12°F; worst case was 14.9°F
    - RH center primary and secondary circuits exhibited different heating characteristics with the primary circuit exhibiting more non-uniform heating
- Phenomenon previously observed on STS-96 field joint heaters

Concern

- Excessive delta between high and low sensors could cause a violation of the upper LCC limit of 123°F while maintaining the lower sensor at the nominal setpoint of 98.7°F

Discussion

- Temperature deltas result from uneven heating due to improper manufacture
- Non-uniform electrical resistance in the various segments of the heater

Technical Issues/Special Topics

STS-103 Field Joint Heater Performance Concern (Cont)

Discussion (Cont)

- Thermal Analysis
  - Performance of each heater has been characterized and maximum temperature variation predicted for each joint at various conditions and heater setpoints
  - Contingency plans developed and coordinated
    - LCC deviation completed to reduce generic LCC limit to as-built minimums
      - Maintains 2X tracking for joint seals
    - OMI deviation completed to reduce heater setpoint from 98° to 90°F and operate RH center heater on secondary circuit
    - OMRSD waiver for heater variation complete
    - Decision tree for night-of-launch contingencies complete
  - Joint seal temperatures will remain within the range certified for flight
  - Maximum predicted circumferential temperature variation assessed and acceptable

Technical Issues/Special Topics

STS-103 Field Joint Heater Performance Concern (Cont)

Flight Rationale

- Non-uniform heaters have been used on previous flight STS-96
  - Heater non-uniformity is predictable and controllable with reduced setpoint
- Using modified setpoint, the RH center secondary circuit, and reduced LCC lower limits, no LCC violations are anticipated during countdown
- Joint seal temperature will remain within the certified range
- STS-103 is safe to fly

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STS – 103 Readiness Assessment

Pending satisfactory completion of normal operations flow (per OMRSD), the RSRM hardware is ready to support flight for mission STS – 103

19 November 1999

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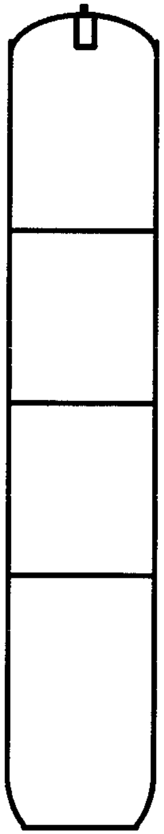
Configuration Inspection

LCC and Contingency Temperatures for STS-103



Heater Location	LCC LH	LCC RH	Minimum Allowable Sensor Temperature* LH	Minimum Allowable Sensor Temperature* RH
Igniter	74°F	74°F	72°F	72°F
Forward Field Joint	70°F**	68°F**	68°F	66°F
Center Field Joint	69°F**	67°F**	67°F	65°F
Aft Field Joint	70°F**	70°F**	68°F	68°F
Nozzle-to-Case Joint	75°F**	75°F**	66°F	68°F

*Launch commit criteria (LCC) contingency temperature in the event of heater failure
**Minimum redlines based on as-built joint capability per LCC deviation LD-067
Note: Calculation includes all standard repair conditions

Technical Issues/Special Topics

Disposition of Prior Technical Issues Specific to STS-103

Technical Issue	Rationale
Nozzle Throat Ring Phenolic Material Testing	Assessments of material acceptance and manufacturing records for STS-103 complete with in-family results Nozzle joint No. 4 primary O-ring minimum as-built footprint is measured during dry fit to assure minimum footprint is assessed for primary O-ring erosion limit case analysis Risk assessment and flight rationale unchanged Trimming of CCP broadgoods for width control implemented on STS-96

Throat Ring Pocketing Discriminator Data

	Build Order																			
Throat Ring S/N RSRM STS	27 56B 79 RH	29 49A 80 LH	30 49B 80 RH	37 57B 85 RH	54 65A 90 LH	56 65B 90 RH	57 66A 91 LH	58 66B 91 RH	59 67A 88 LH	60 67B 88 RH	61 68A 95 LH	62 68B 95 RH	63 69A 93 LH	64 69B 93 RH	65 70A 96 LH	67 70B 96 RH	68 71A 99 LH	71 71B 99 RH	74 73A 103 LH	75 73B 103 RH
Performance*	P	P	P	P	N	N	N	N	N	N	N	N	N	N	N	N	n/a	n/a	n/a	n/a
LHMEL Tests	VH	M	VH	VH	VH	VH	L	L	L	H	L	L	L	H	L	VH	L	L	L	L
Plasma Torch** @ 800 Btu	VH	H	VH	L	L	M	L	L	L	L	VH	L^+	L^+	M^+	L^+	H	L^+	No † Test	No † Test	No † Test

* N = nominal, P = pocketing, P = slight pocketing
** Propensity to pocket: L = low, M = medium, H = high, VH = very high
+ 1450 Btu data
† Plasma Torch not operational. Plasma torch testing not a formal requirement. Previously presented flight rationale unchanged